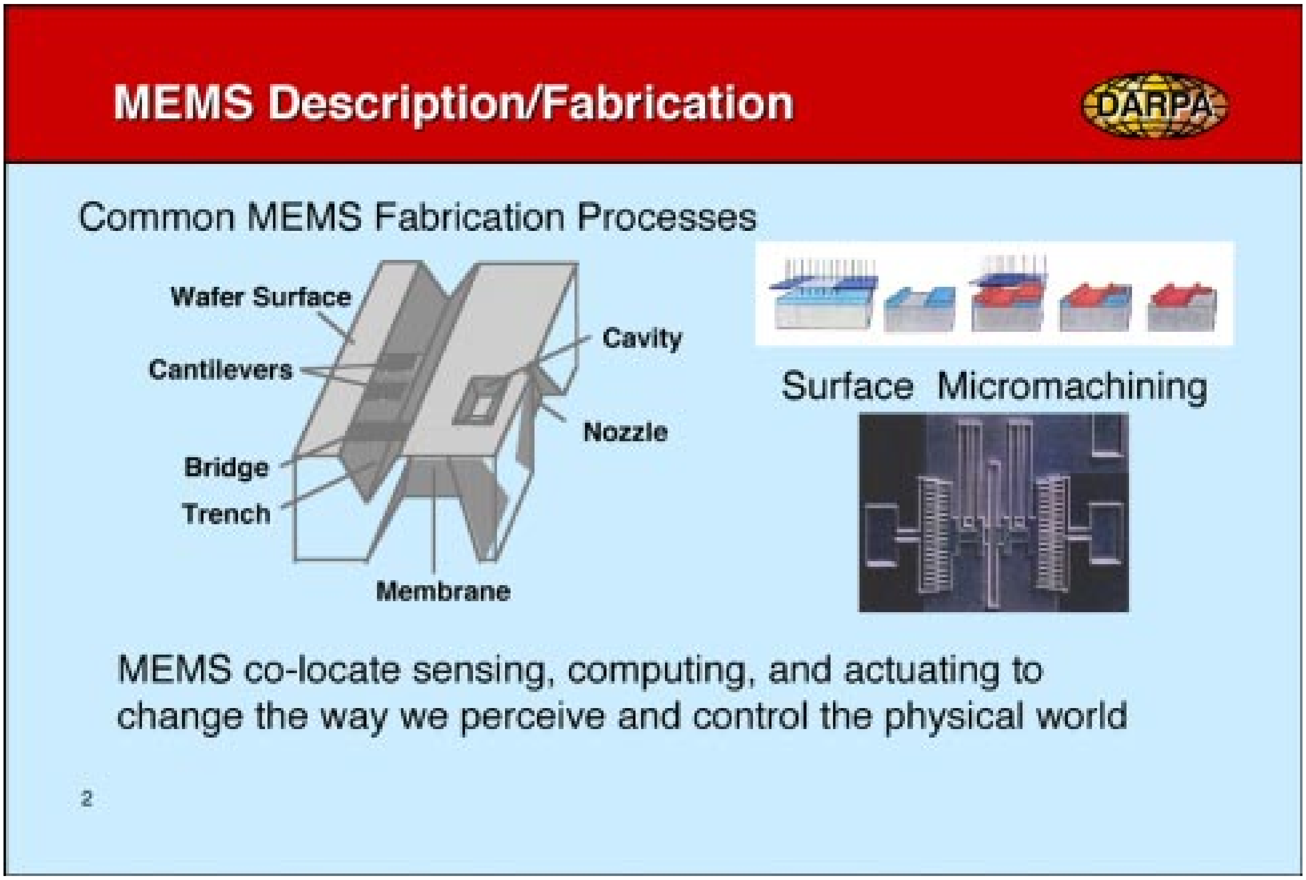
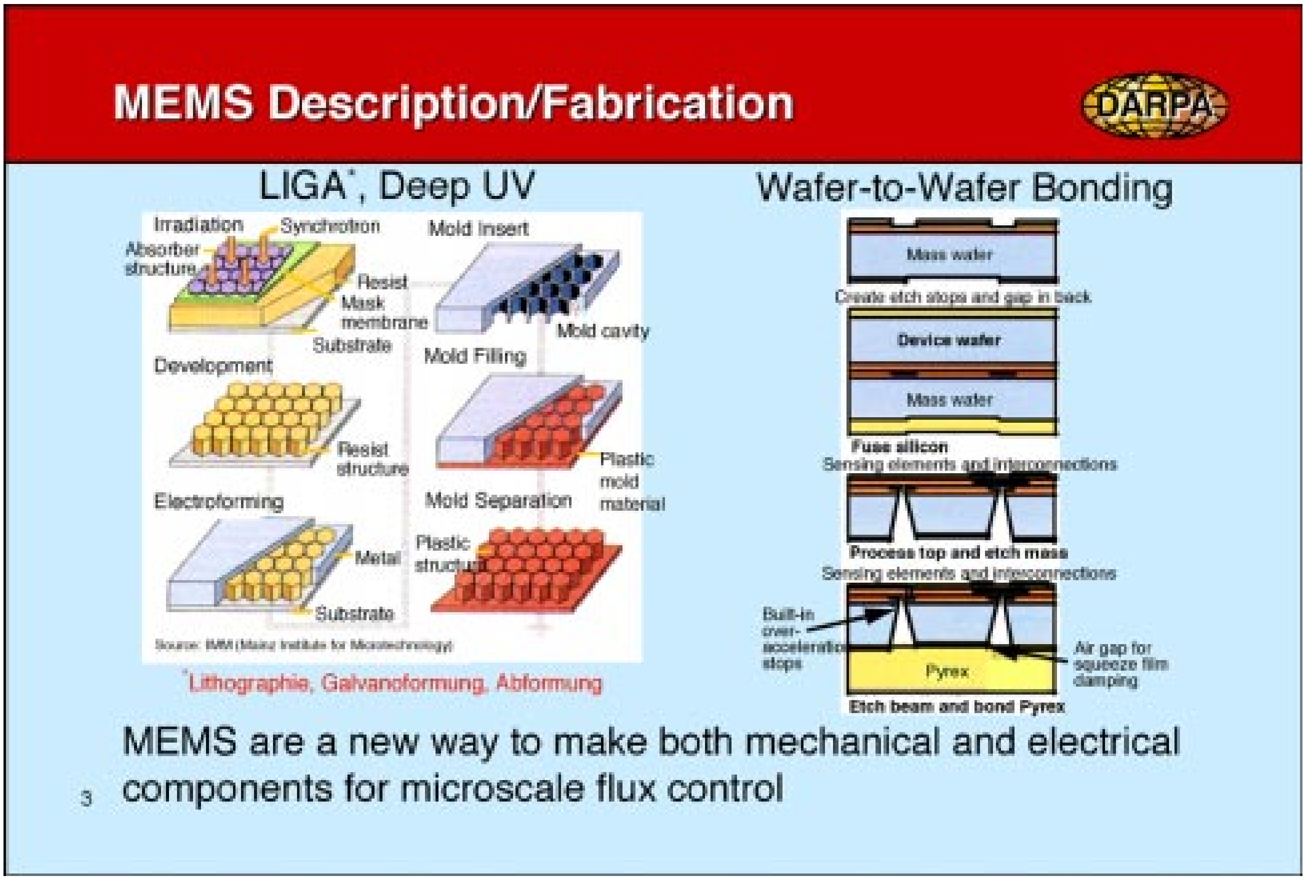
Good Morning, everyone. I am the new DARPA/ETO MEMS Program Manager, taking over for Ken Gabriel in his specific capacity as MEMS Program Manager of MEMS. Ken is now a Professor at Carnegie Mellon University, and today I’m happy to be briefing you on the DARPA/ETO MEMS Program. MEMS are truly a breakthrough technology.



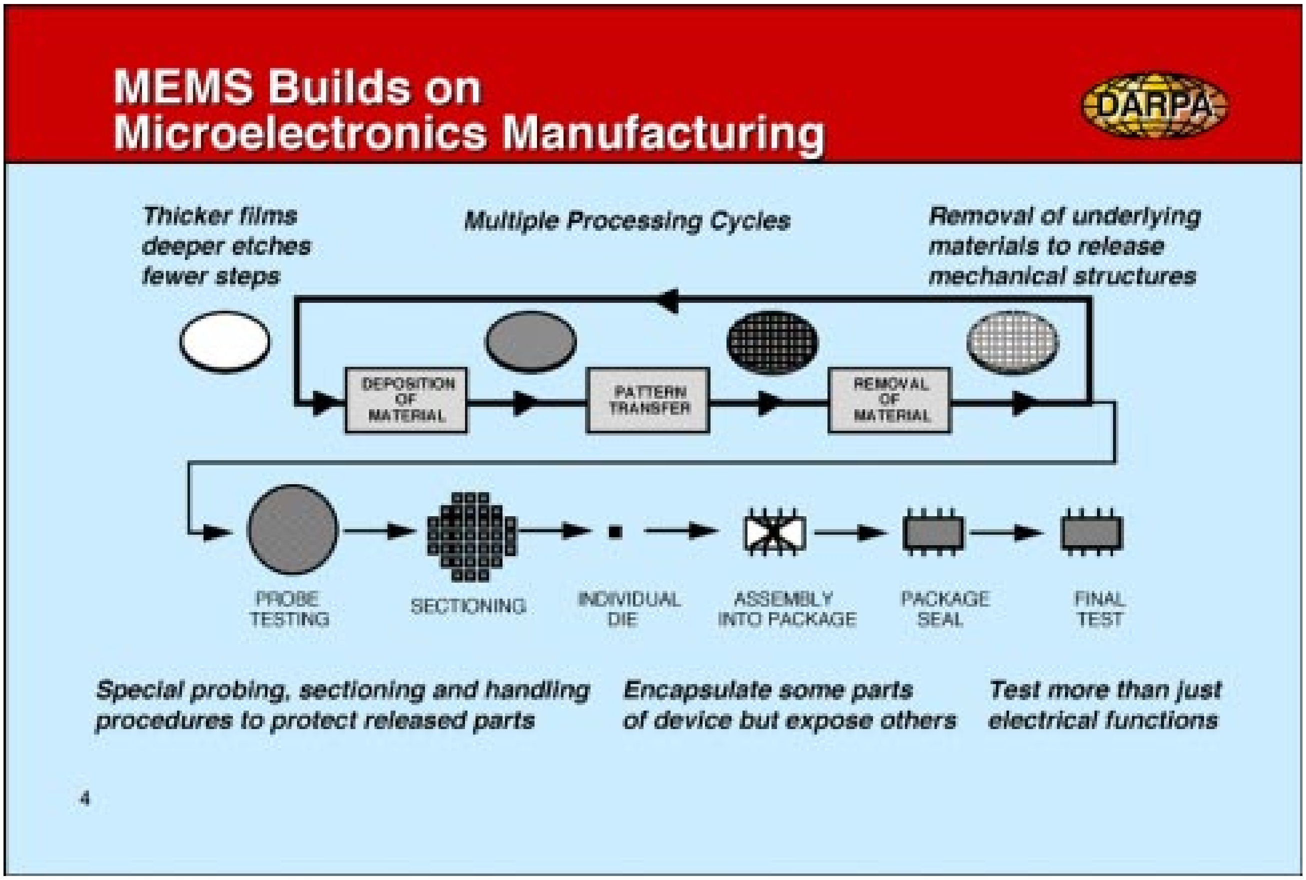
The acronym, MEMS, stands for “Micro Electro Mechanical Systems.” MEMS are composed of electronics and mechanical structures on the microscale. As such, they can include fluidic systems, optical systems, electromagnetic systems, electrostatic systems, in fact, almost any actuation and/or transduction technology that may occur on the macroscale.

Since the electronics and mechanics are both incorporated on the microscale, MEMS make possible the co-location, on the microscale, of sensing, computing, and actuating. That is, at each and every discrete point on the microscale, one may have, simultaneously, sensing, computing, and actuating all going on. In this sense, MEMS are unique in that they can control flux at high spatial resolution and at high frequency response. And these fluxes include electron flux (current), as well as photon flux, heat flux, fluid flux, electromagnetic flux. And it all can be accomplished at low cost.

To the left is a schematic of bulk micromachining. To the right is a schematic of surface micromachining.

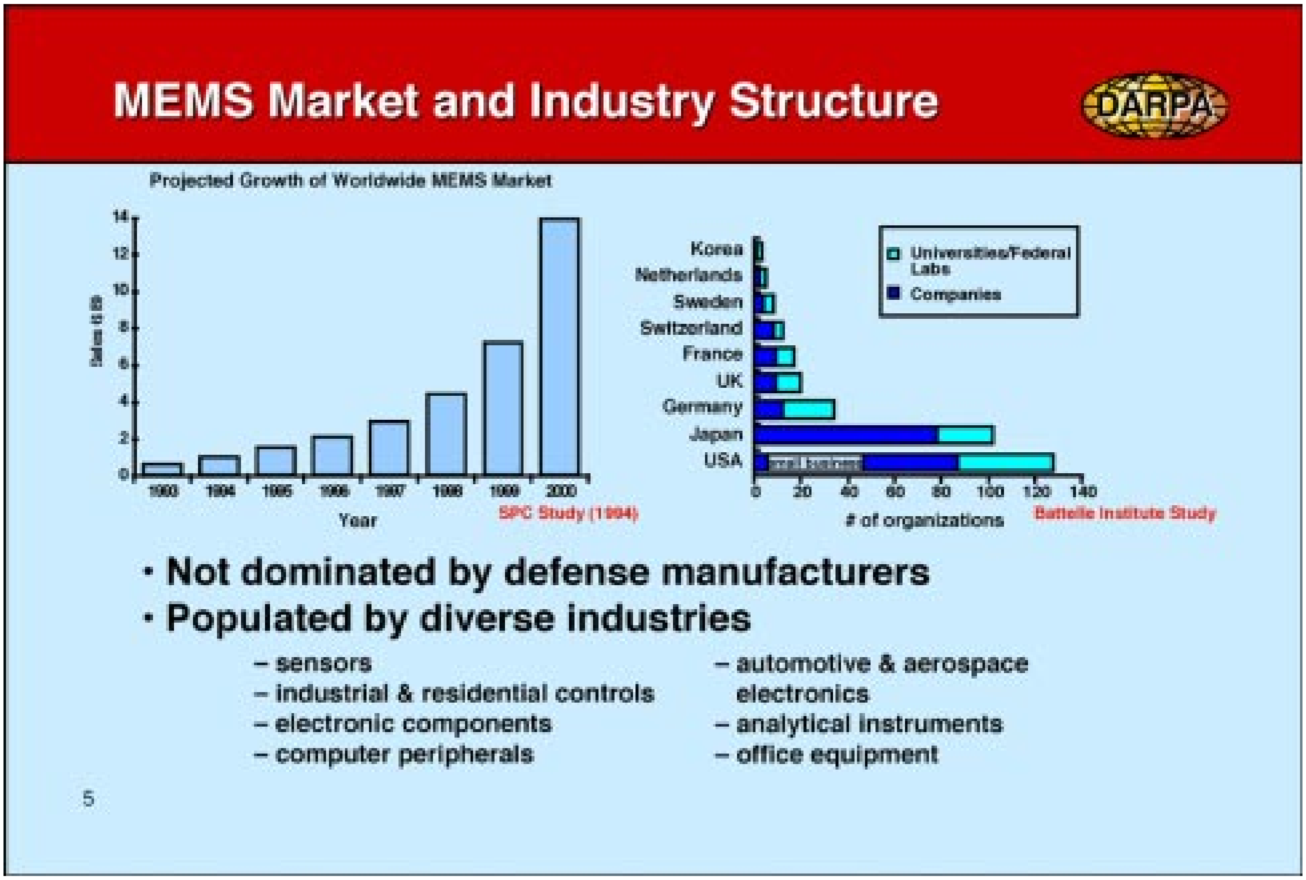


There are many other methods of micromachining. Almost as many as one can imagine. Here I show two other popular methods to fabricate MEMS. On the left, the LIGA process, invented in Germany. And on the right, wafer-to-wafer bonding, being pursued by several companies and Universities in the United States, as well as other laboratories around the world.

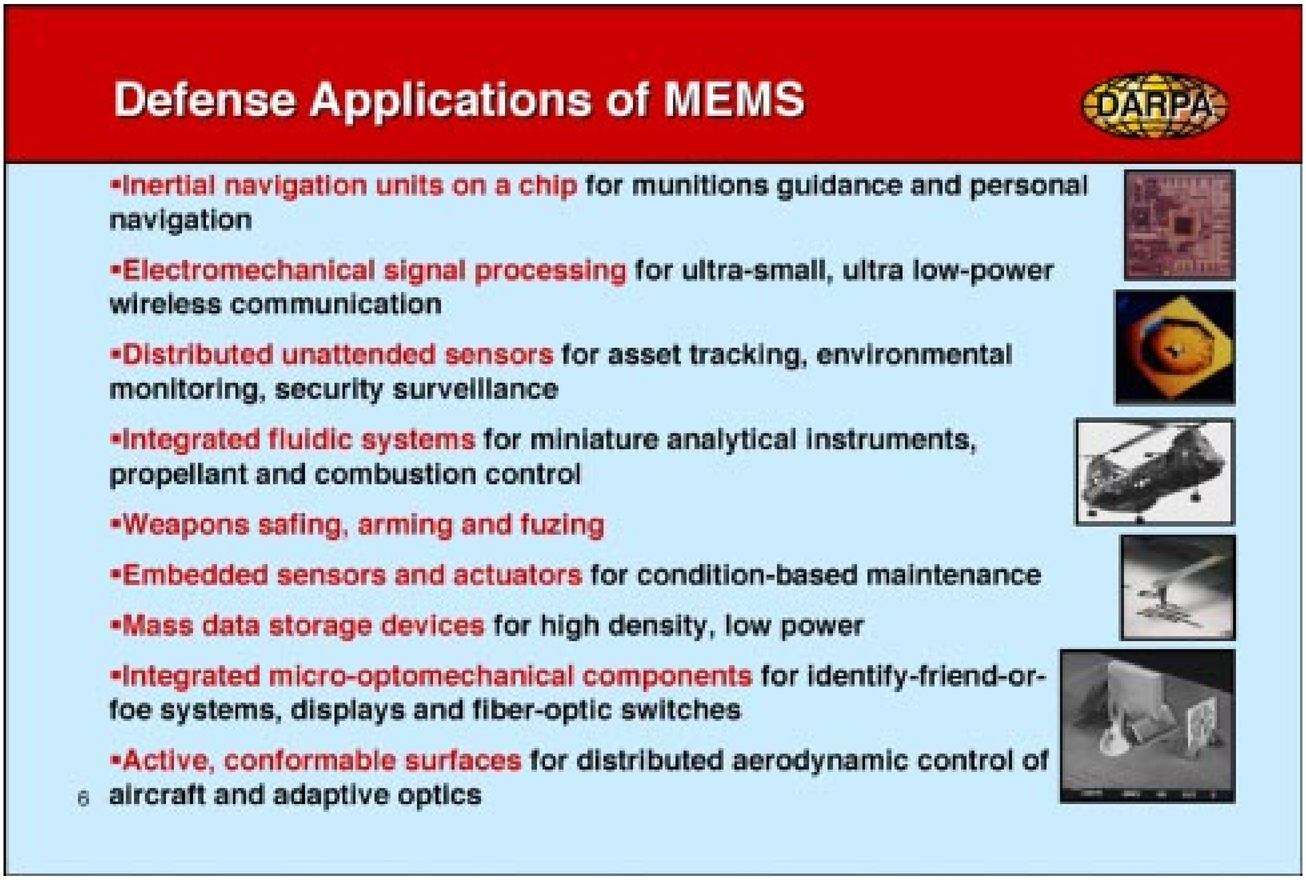


Why is MEMS getting off to such a fast start? Well, one major advantage MEMS have is the large infrastructure in processing silicon wafers. This infrastructure was invented and funded by those working in microfabrication of electronic circuits. MEMS fabrication utilizes many of these methods, albeit with the process parameters changed in order to obtain functional mechanical structures as well as the requisite electronic structures.

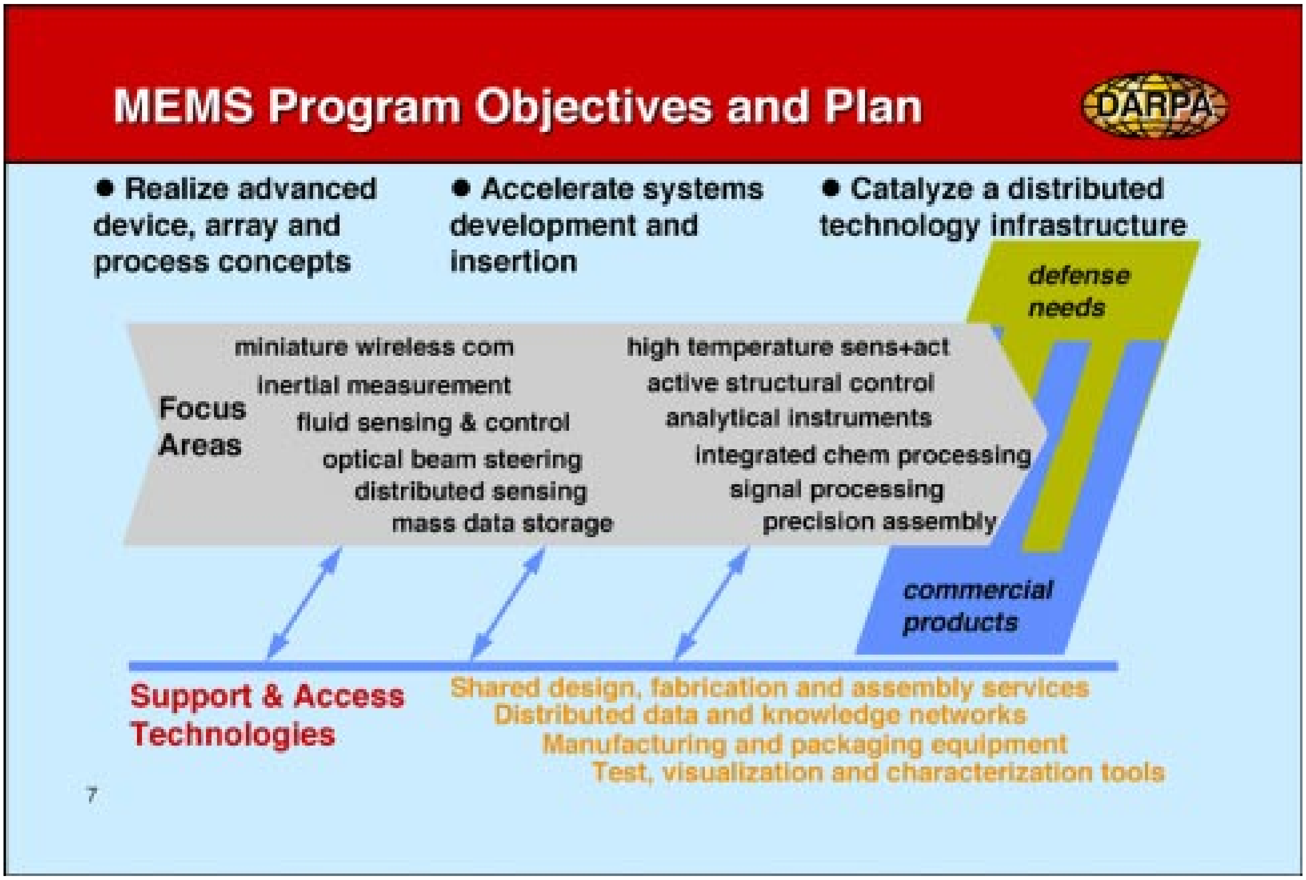
This slide shows the current thinking on MEMS fabrication and packaging. As the next few years pass, I anticipate that this paradigm will change, and with greater frequency, MEMS will be fabricated directly onto the device into which they are to be integrated.



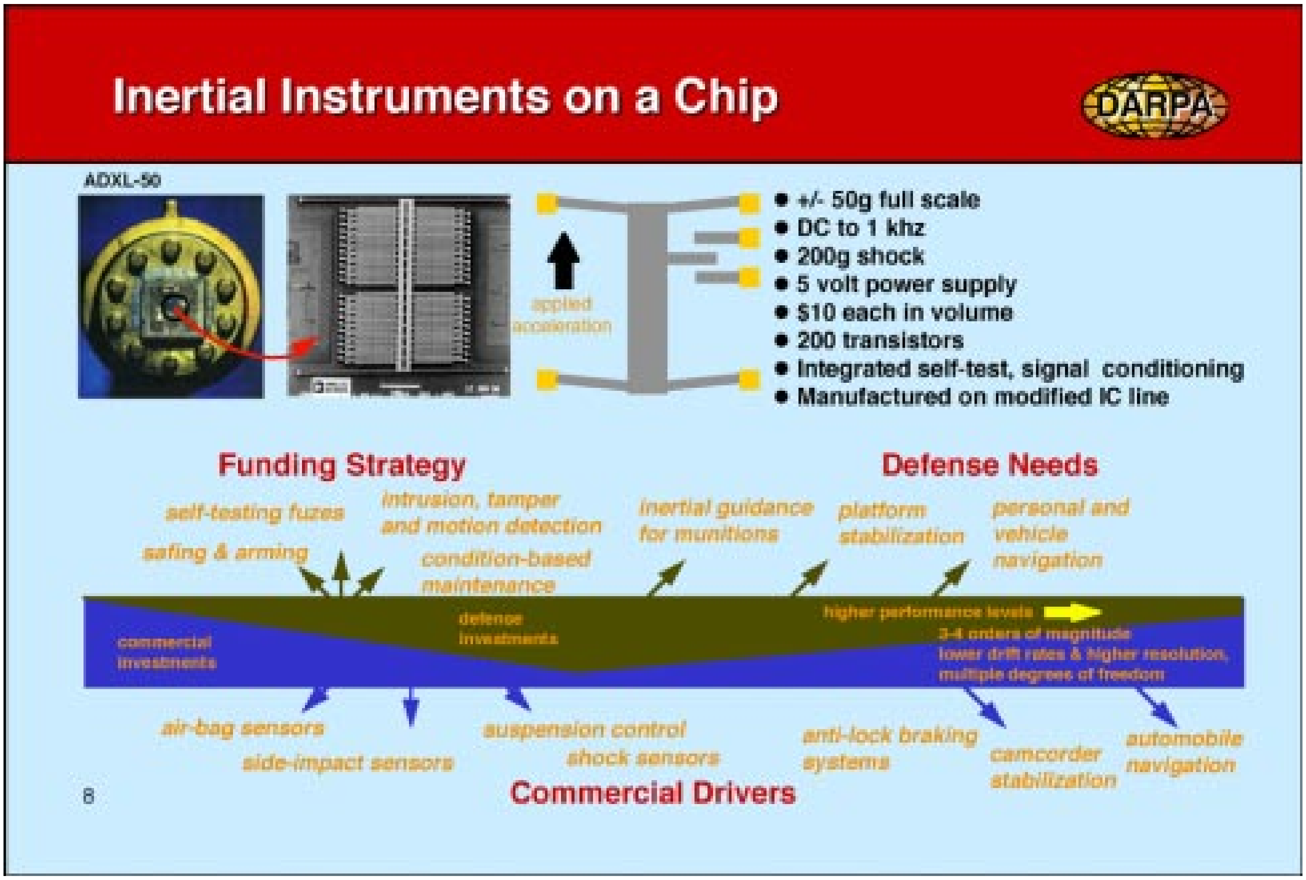
What does this emerging field of MEMS look like? One way to understand it is to take a look at who is making MEMS. Here is a snapshot of MEMS manufacturers all over the globe.



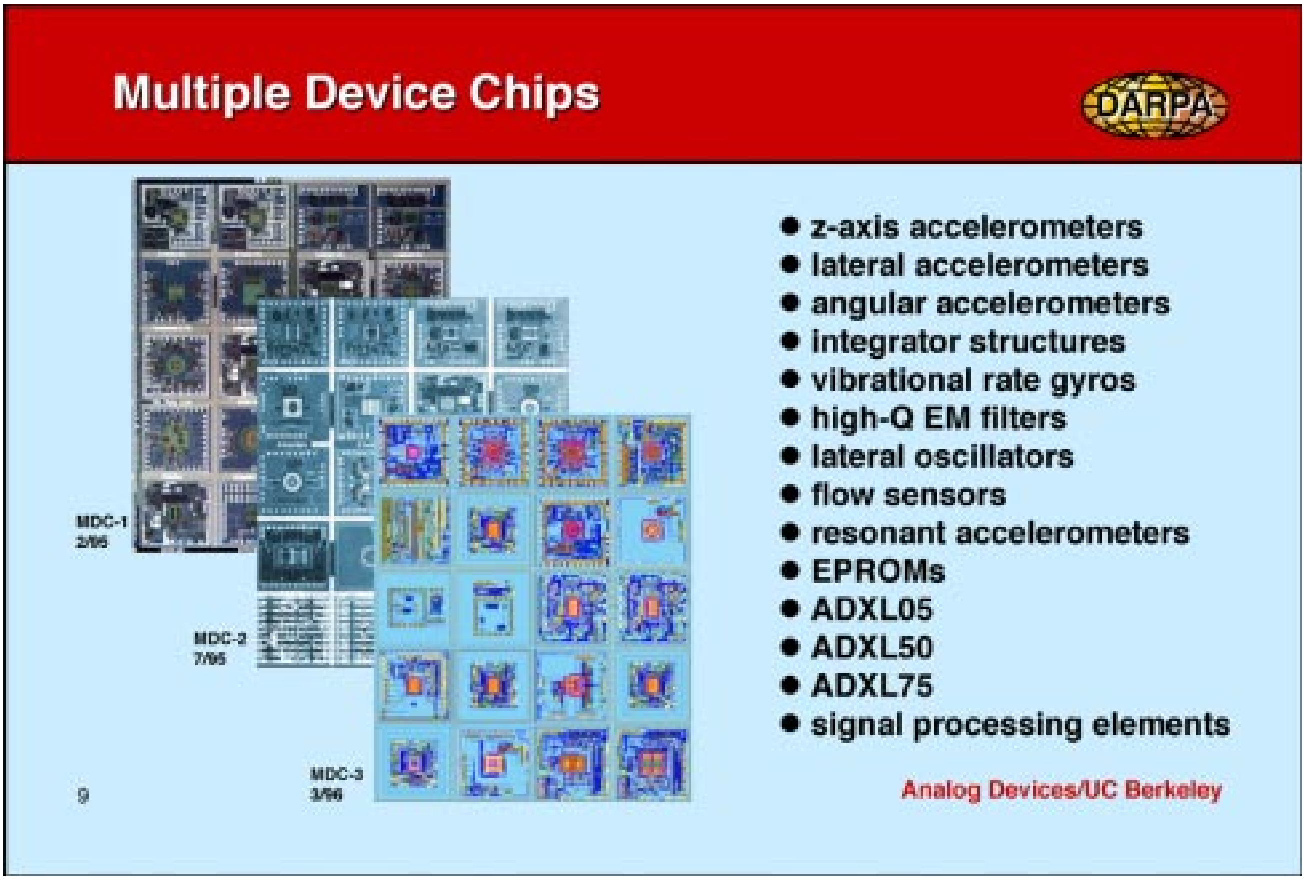
The bottom line for the DARPA are Department of Defense applications of MEMS. Here are nine examples of MEMS applications to DoD needs.



The basic objectives and plan for the DARPA/ETO MEMS Program are threefold: 1) realize devices, arrays, and processes, 2) accelerate the development of systems, and 3) make sure there is a distributed fabrication technology infrastructure in place nationally so that MEMS are available in the quantities needed to make a commercial impact. There are several focus areas to which MEMS are being applied, and these focus areas span both defense needs and commercial products. But common to all are the support and access technologies that make MEMS possible for both the DoD and the commercial sector.

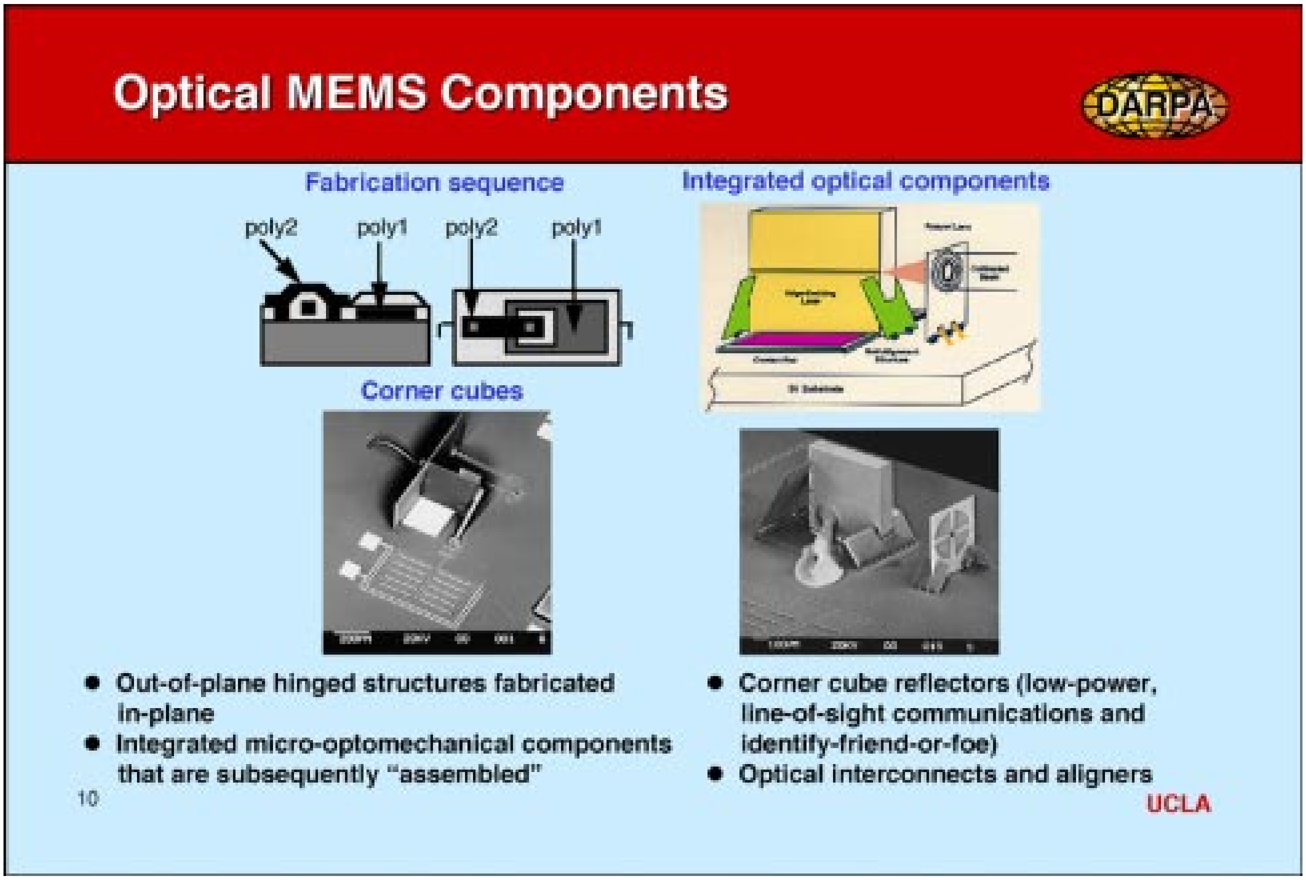


On the upper left I show an example of a device that has achieved both commercial success and growing DoD relevance. This is the Analog Devices, Inc., micro accelerometer, the ADXL50. How might this one device affect both the Defense and the Commercial sectors? Let’s look at the variety of applications (Defense above the green bar, Commercial below the blue bar). Note also that the leveraging of investment by DoD (DARPA in particular) is anticipated to ramp up to a point, and then decrease as the commercial sector begins to make major investments of its own. DARPA money is intended to spur the development of new MEMS, but not to permanently subsidize their manufacture.

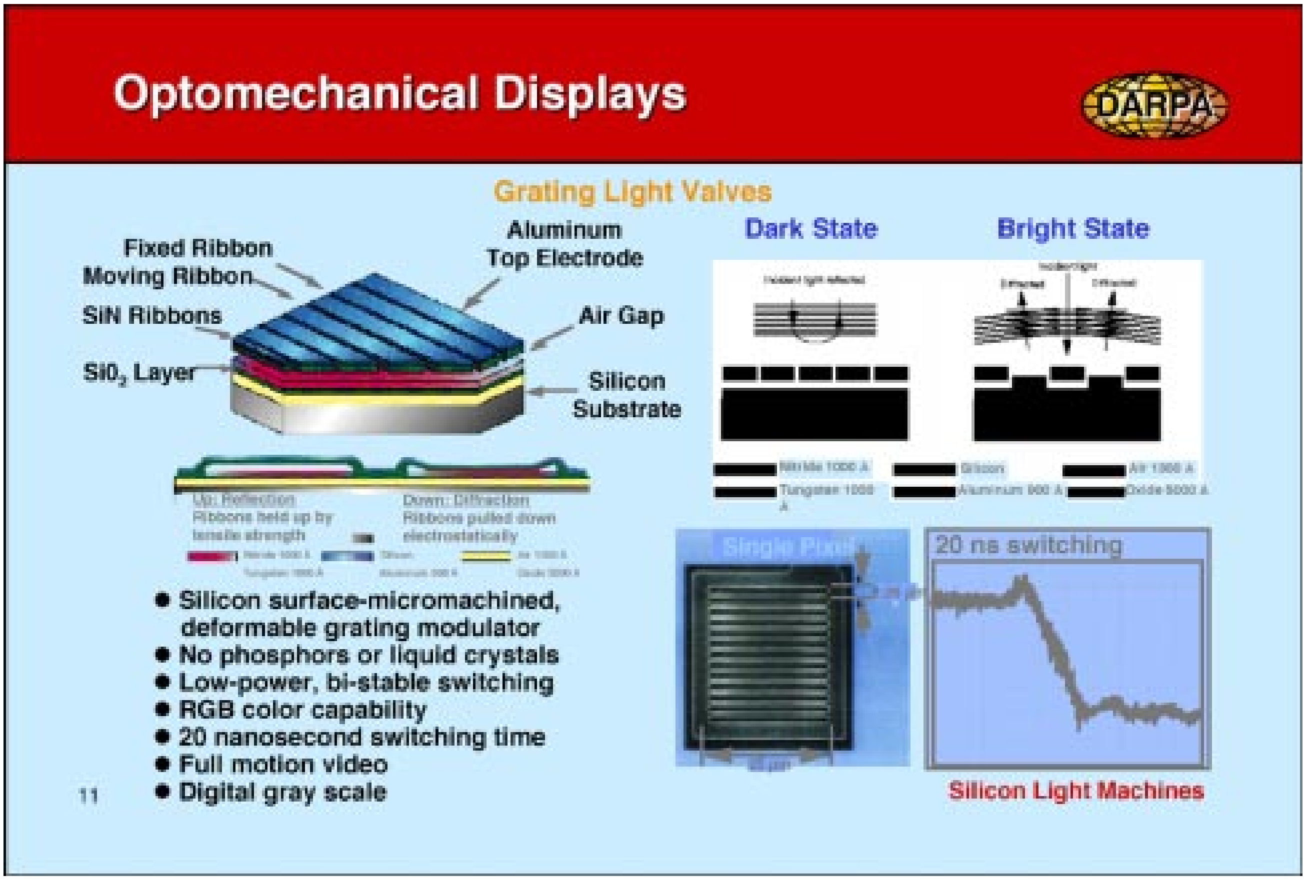


For the next part of my briefing, I review a series of interesting projects funded by the DARPA/ETO MEMS Program. Many of these were put into place by my astute predecessor. I'm carrying these forward, as well as initiating more projects during my tenure as MEMS Program Manager.

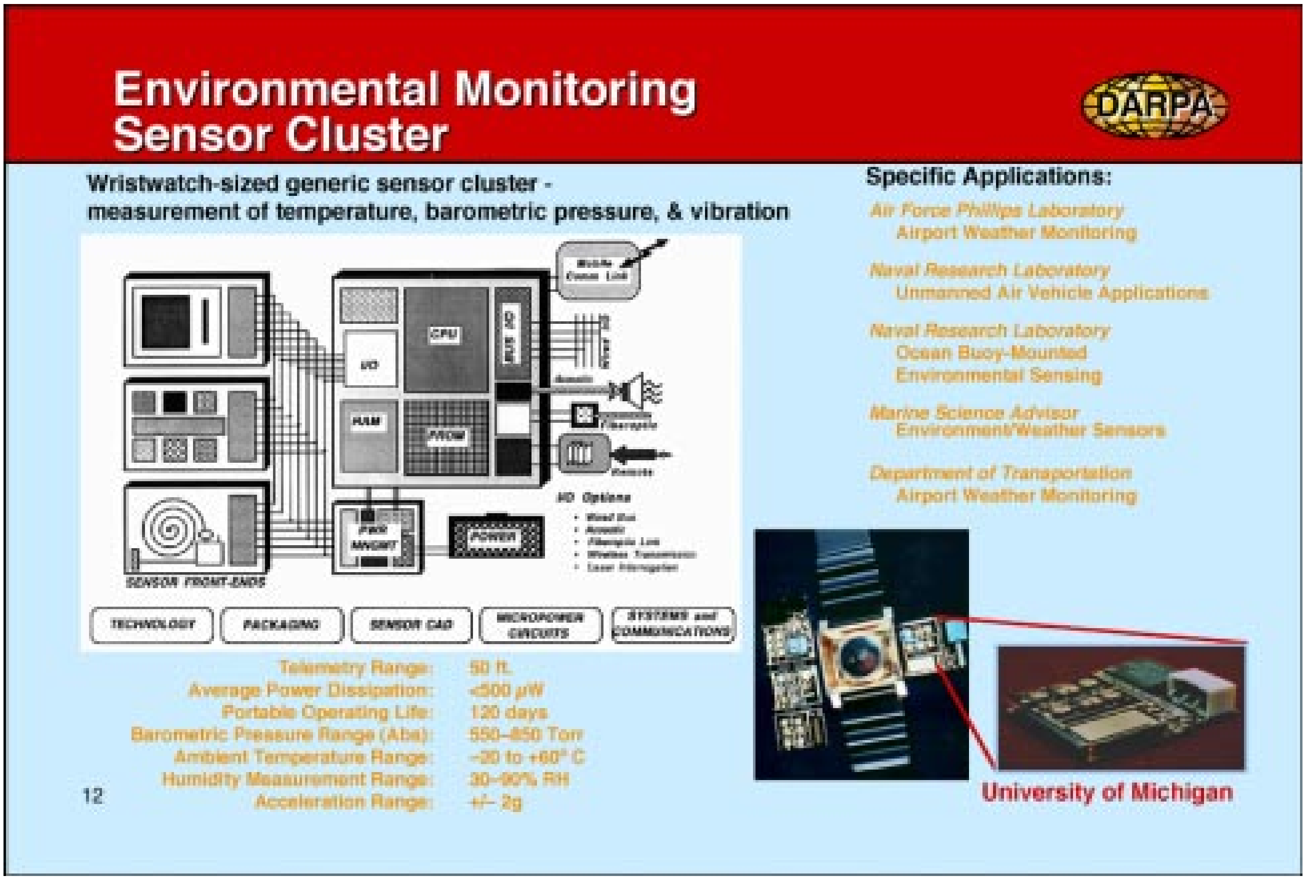
Here I show the "multi project chip" fabricated by the team of Analog Devices, Inc., and the University of California at Berkeley. Note that in one technology and on one wafer one may make devices falling into these 14 categories. And we are not limited to just these 14. The applications of the devices fabricated on this one chip are many.



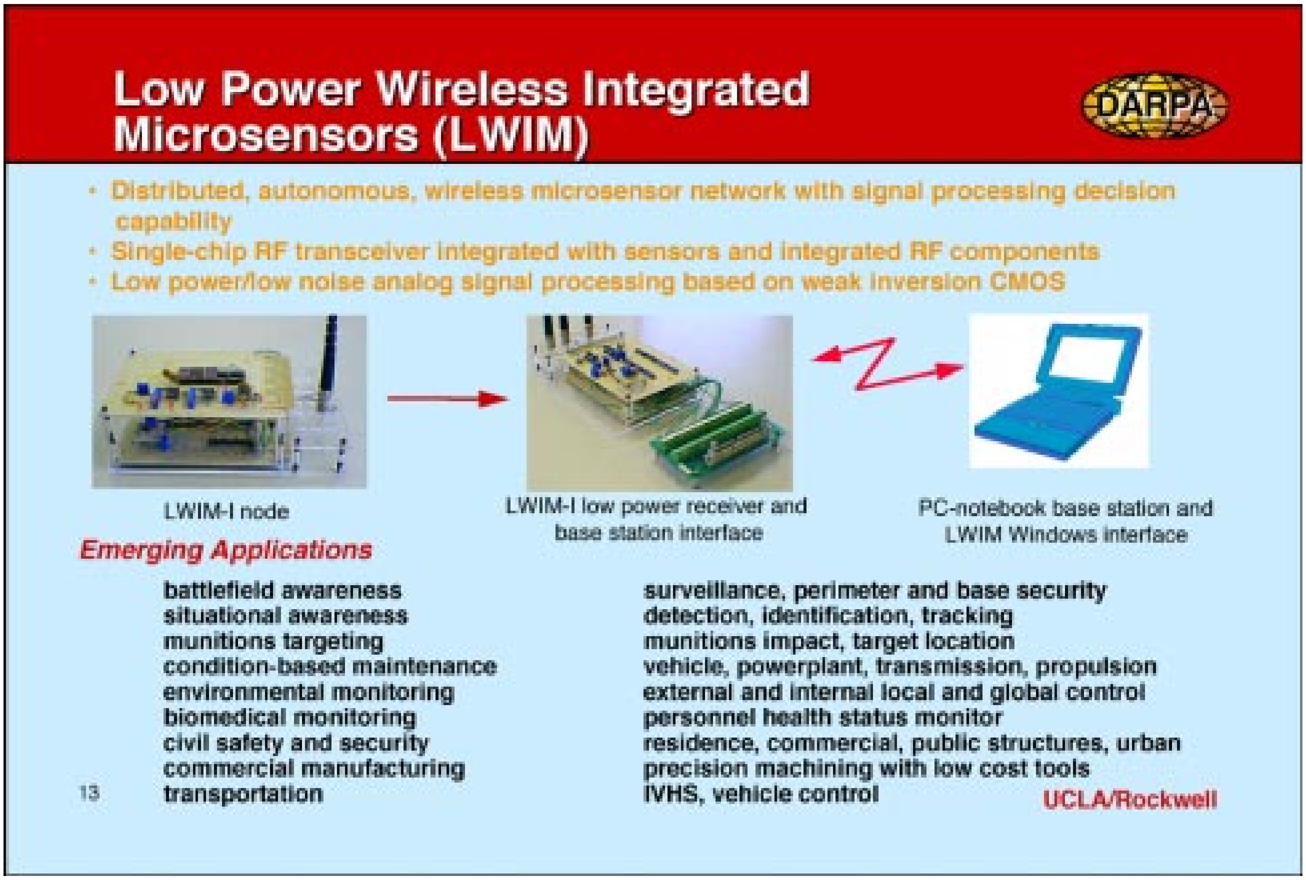
Here is work with roots at UC Berkeley, and major development at UCLA, as well as continuing progress at UC Berkeley. The innovative concept here is the "fold-up" assembly of planar structures into three-dimensional structures. Since microfabrication depends on the photolithographic process, the advantage here is that well-known planar fabrication processes may be used to build the "unfolded" version of three-dimensional structures, and then a process as simple as a water-rinse may be used to push and lock the structures into their three-dimensional position.



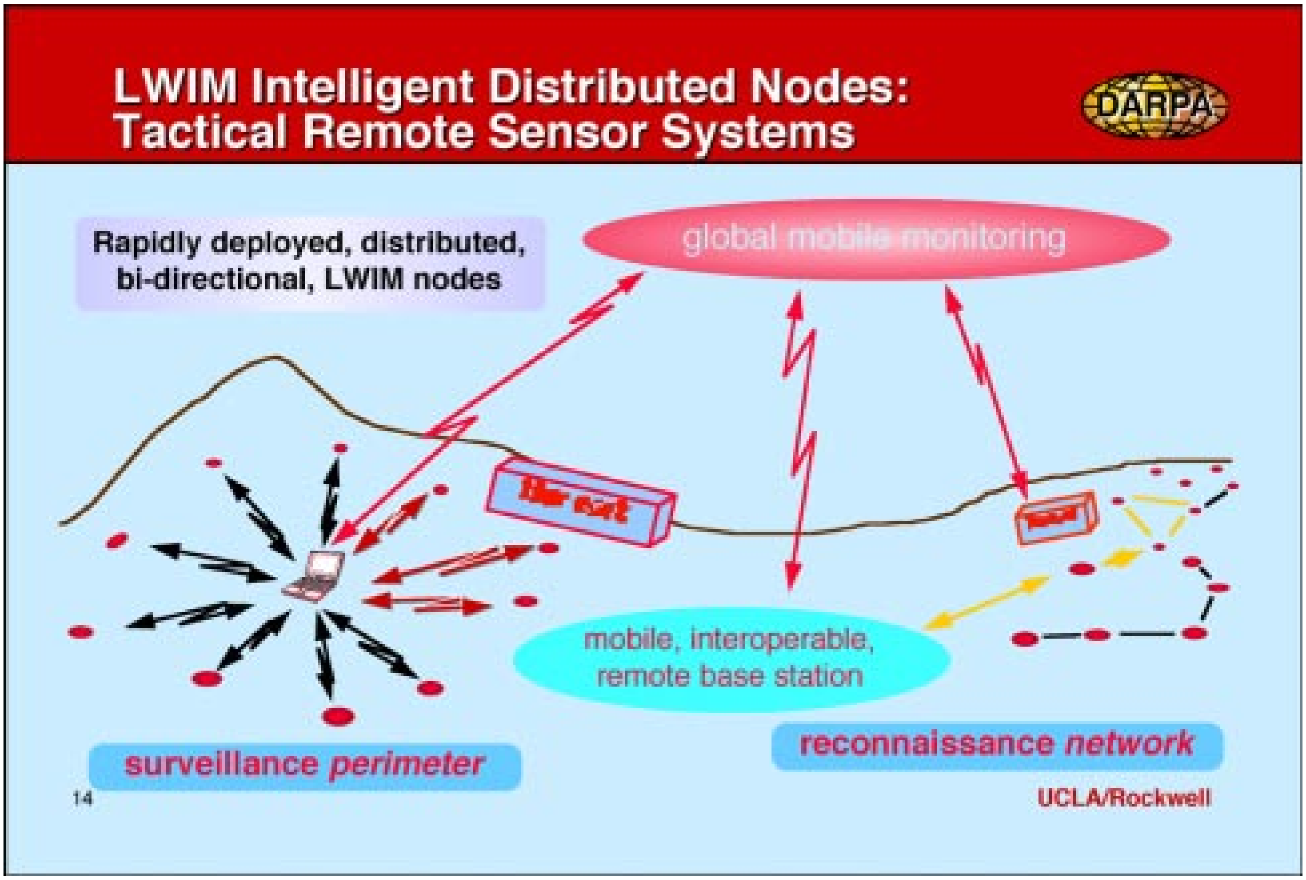
There is more than one way to apply MEMS to optics. The DMD depends on having multiple sources of light, each with a different color, to form a color image. Here is a way to form any color of light from a plain white illumination. The moving ribbons being pursued by Silicon Light Machines actually use interference to construct the correct wavelength of light to form images. This grating moves in response to electrical signals, making possible an array of “pixels” that may assume any color at any time.



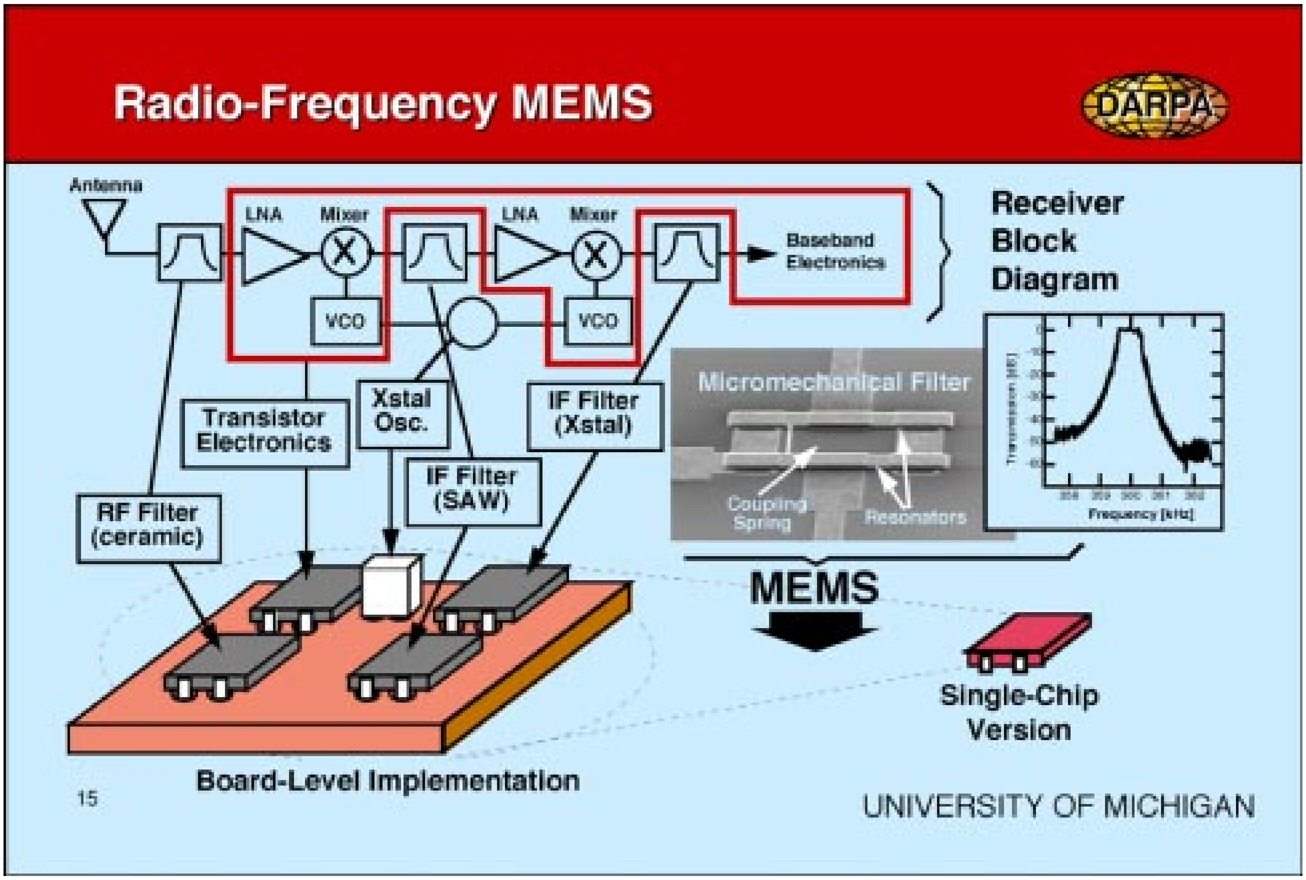
MEMS may be used to revolutionize sensing over long distances and in remote locations. Here is a miniature sensor cluster being developed by researchers at the University of Michigan. This cluster is being investigated by over five government organizations.



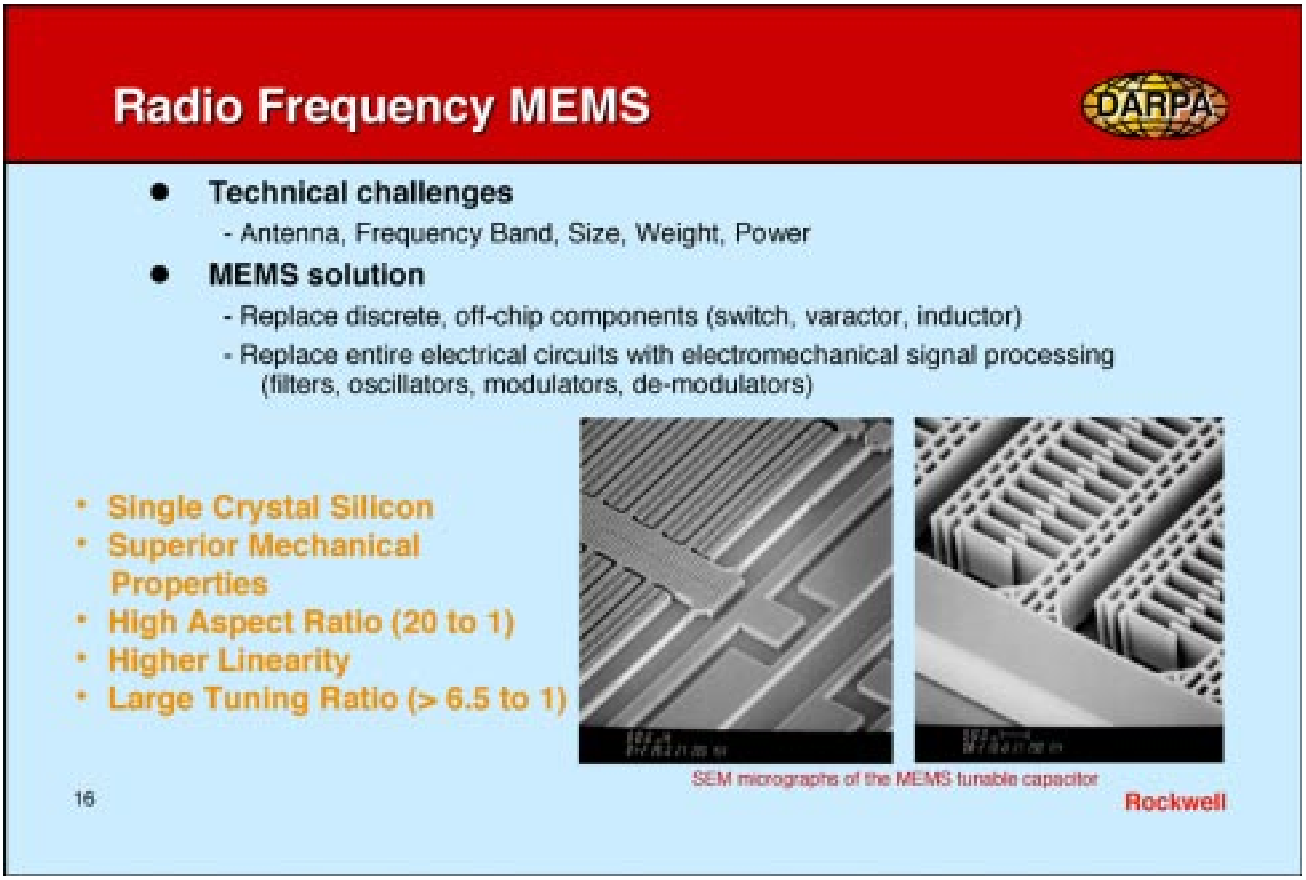
The LWIM project, jointly operated by UCLA and Rockwell, is pioneering a low power, wireless microsensor network with extreme application to battlefield awareness.



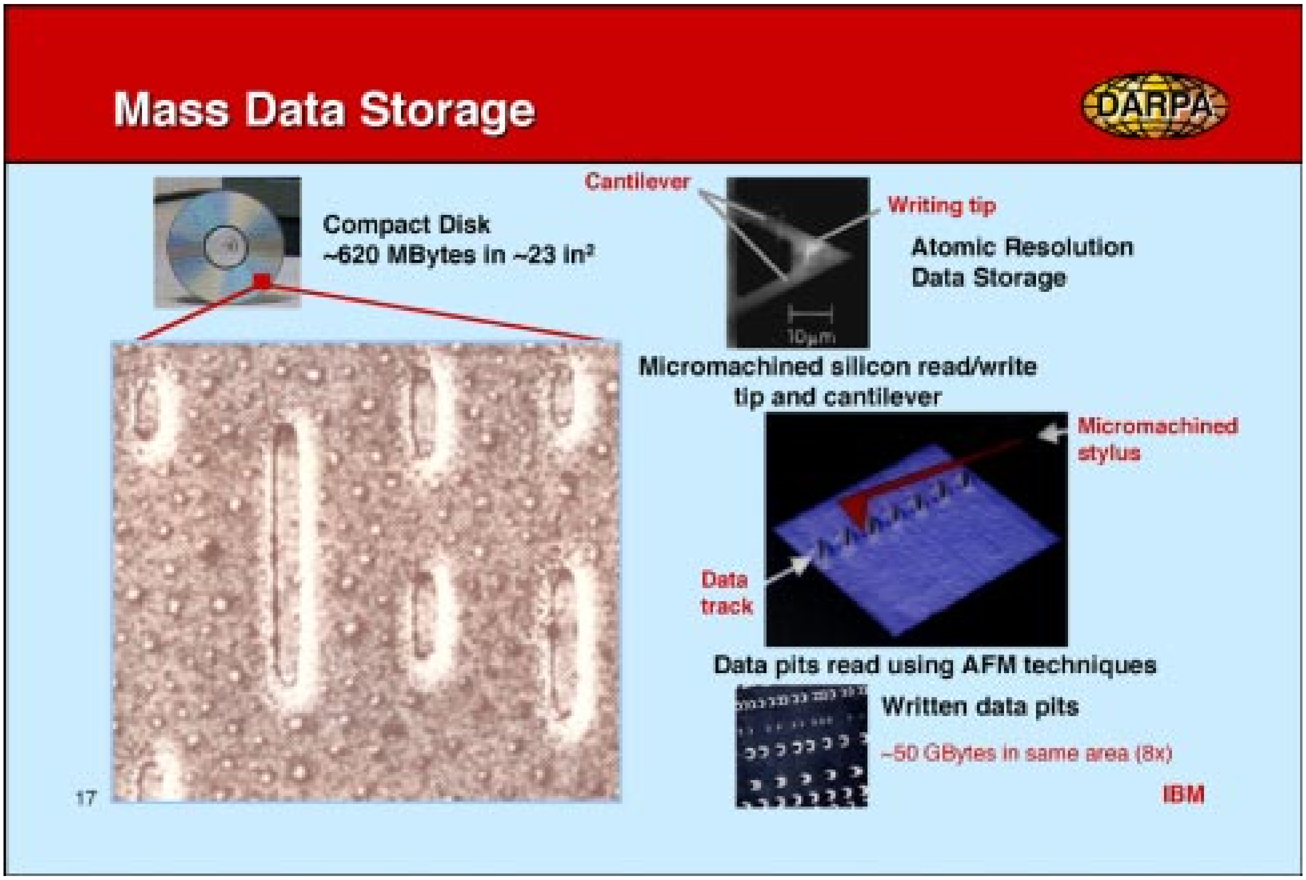
Here are the two ways LWIM system may operate. A distribution of nodes (randomly dropped from an aircraft, for example) need not be placed in any precise locations. When on the ground, they self-organize into a network that can either establish a perimeter for surveillance, or, by passing information among themselves, work as an effective reconnaissance network. Communications with either ground or air units is made possible by LWIM units that either work together, or by one particular LWIM unit of higher radio broadcast power.



I believe that MEMS will play a role in the miniaturization of transceivers. On the lower left is shown a board-level implementation of a radio. Most of the components there are not integrated into the transistor electronics chip. MEMS will make possible that integration so we may achieve, truly, a radio on a single chip. This slide depicts work ongoing at the University of Michigan.

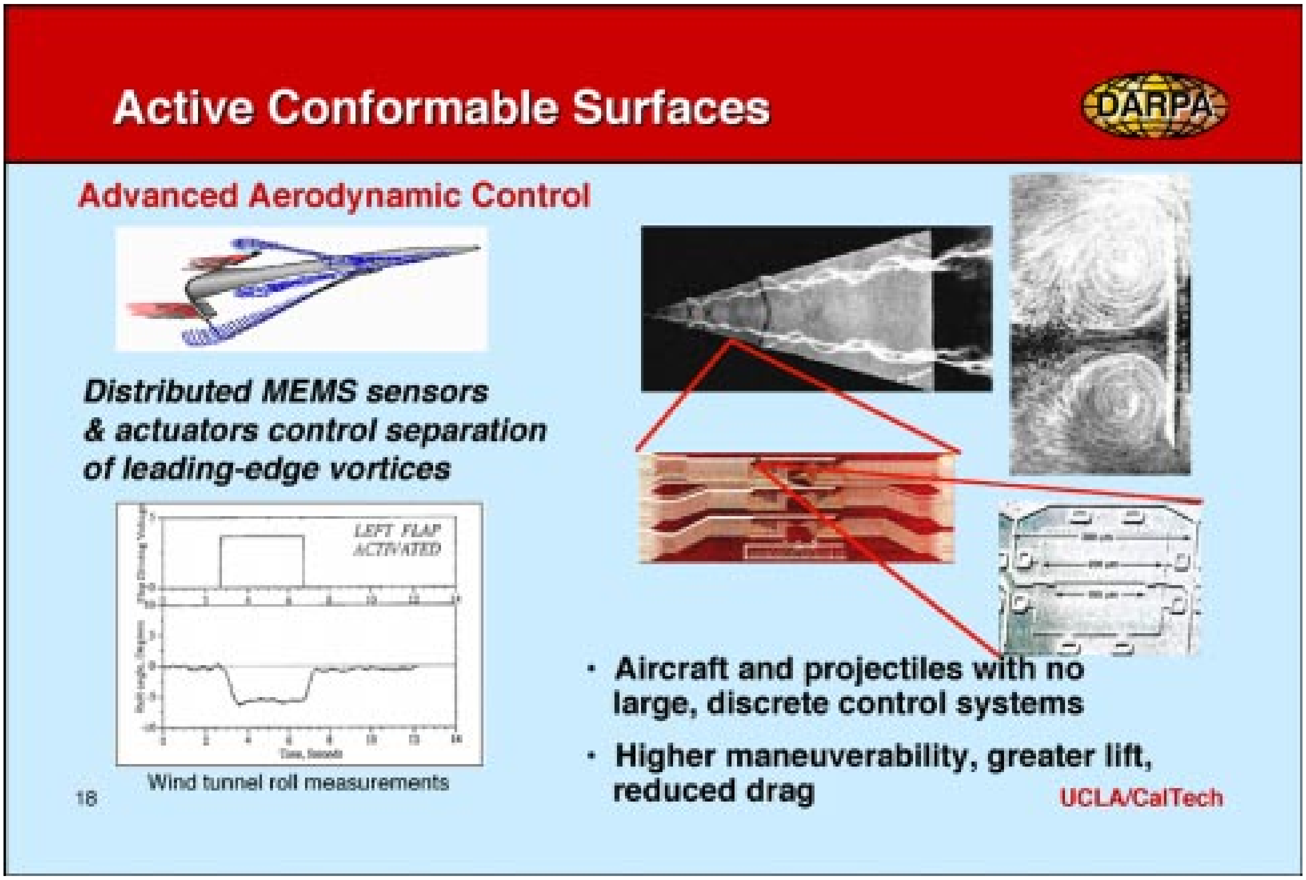


We see here just one way in which MEMS can bring about the miniaturization of radios, being pursued at Rockwell for the miniaturization of Antenna Interface Units. Below, I show a MEMS varactor, basically just a capacitor whose value I can change with a voltage command. With this varactor, I can drastically reduce the size, weight, and power of radios, all the while increasing performance, since the MEMS varactor has lower insertion losses than macro devices do. Along with varactors have been constructed MEMS switches and MEMS signal processing networks. These technologies all work better than their electronic counterparts. As a Mechanical Engineer, I'm thrilled by all of this since it means that electromechanical signal processing may be surplanting purely electrical signal processing and this represents the Mechanical Engineering revenge upon the transistor!

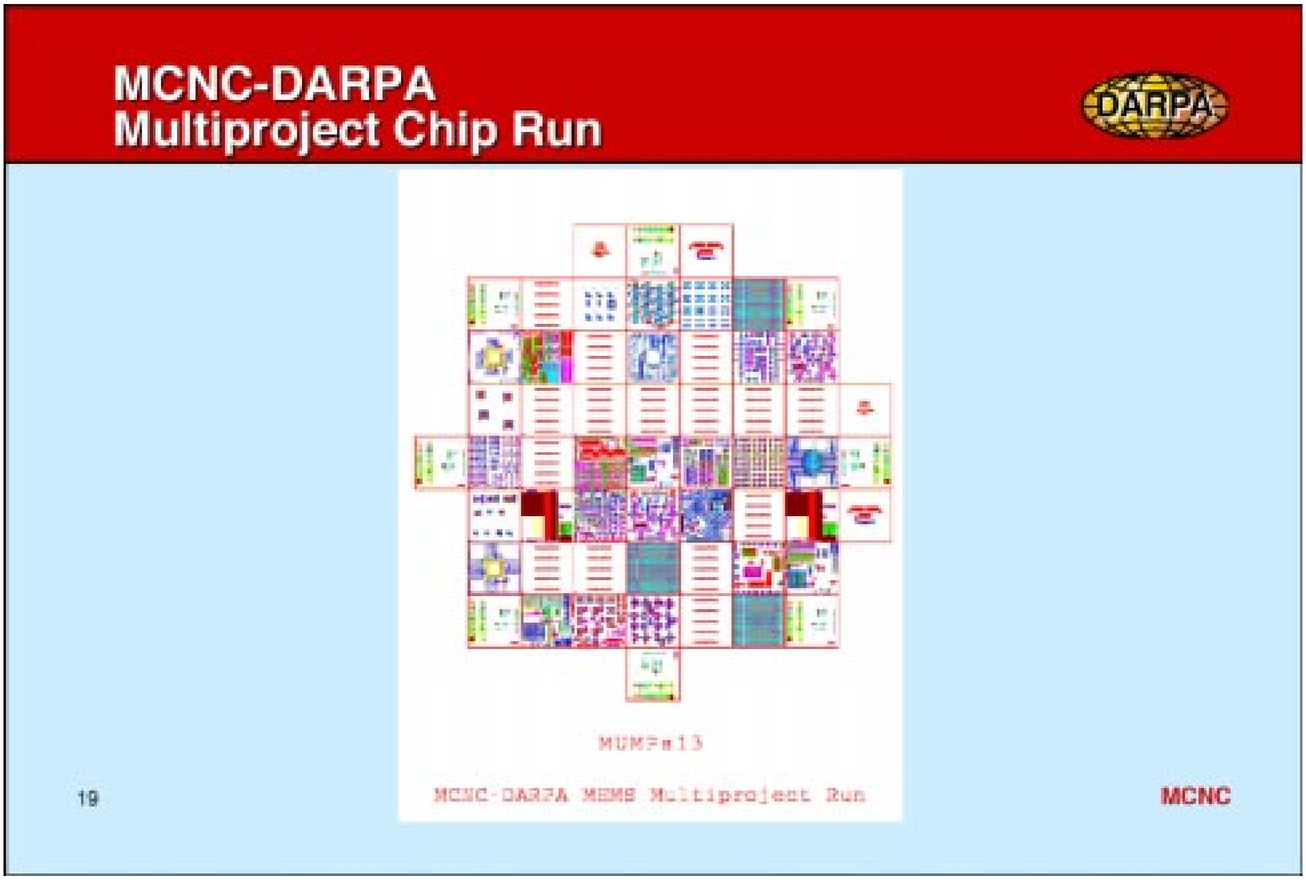


On the other side of the country, IBM in San Jose is pursuing a method of reading mechanical pits arranged into data tracks.

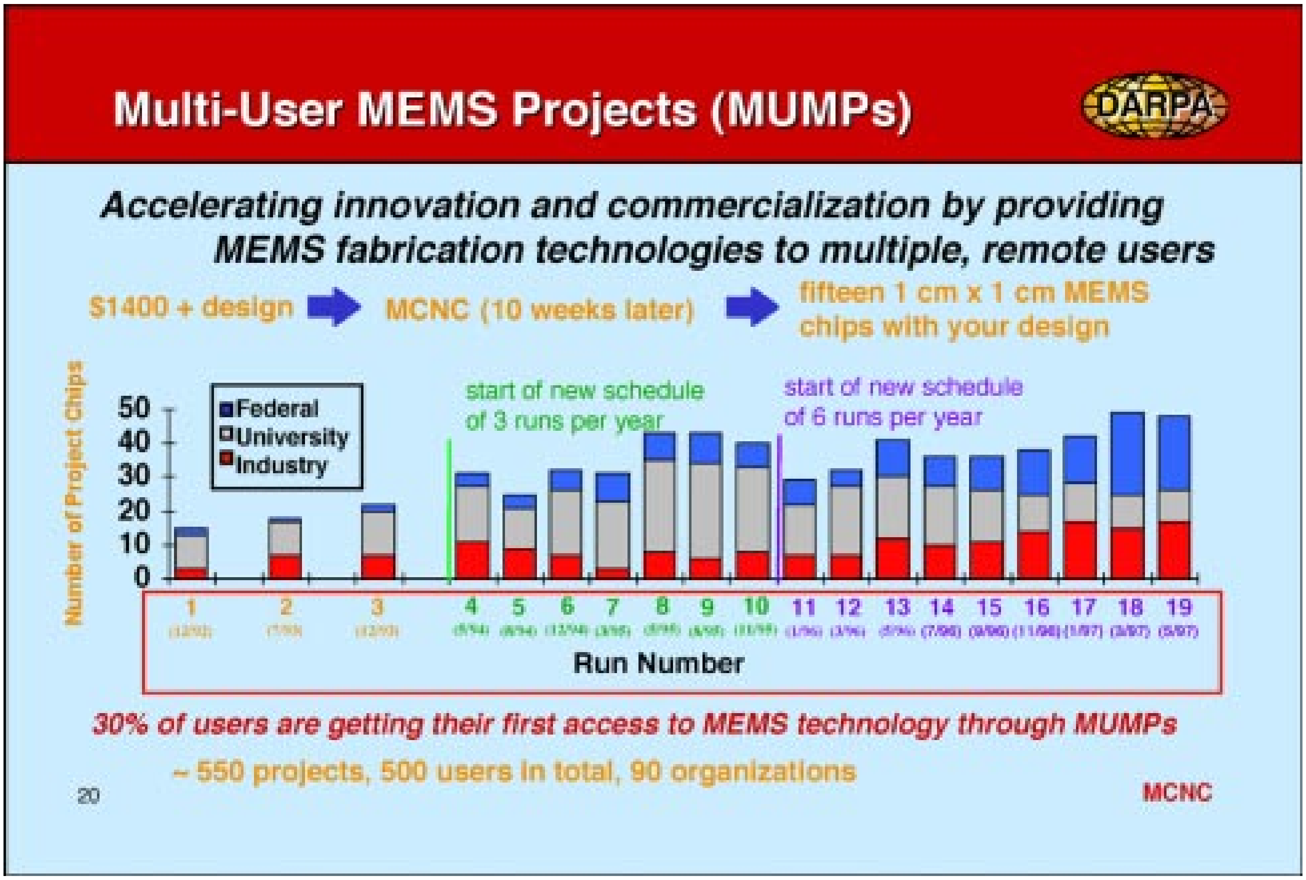
A compact disk is known for its incredible data density. This is approximately 620 Megabytes in just 23 square inches. But using this method of mechanically reading pits in a carbon film, one may achieve a storage of over 50 Gigabytes in the same area! An increase of almost 100x. What's happening here is that an incredibly small writing tip is scanning the surface, staying just a small fraction of an atom away, since it actually measures the repulsive force from individual atoms. As the tip is actuated up and down to avoid contact with the surface, a control system decides if a bump is encountered, and the data is encoded in the pattern.



Let's switch from the micro to the macro. One of the hallmarks of a great MEMS system is its ability to control flux on the microscale in order to obtain effects on the macroscale. This project (joint between UCLA and Cal Tech) showed just how to do that for aircraft. The separation of the leading edge vortex on a swept airfoil can be used to strongly adjust the lift and drag on that airfoil. Control that, and you control the airplane. But the flow separation can be "tripped" by just the tiniest of bumps … if you know exactly where to put the bump. Now, make the bump bigger and smaller and you can trip or not trip the flow separation. And viola … microactuators moving around airplanes! Now, this hasn't been done for full-sized aircraft yet, but recent work on 1/6 size scale models shows that MEMS actuators can actually be used to maneuver for climb, descent, rolls, and turns.



Wide access to MEMS Fabrication is a major goal of the DARPA/ETO MEMS Program. Here is a multi-project chip fabricated at MCNC, the Micromachining Center of North Carolina. Of special note is the fact that chips for over 40 users are all fabricated on this one wafer, minimizing the cost to each user.



All you need is approximately $1400 and a PC. After downloading the software to do your layouts, you can virtually upload your artwork to MCNC and, in 10 weeks, get a dozen chips with your own design on it! This has been going on since May 1994, and the frequency of runs has increased from a few per year to six per year. Note the graph … Federal and Industry Labs are using MCNC to a great extent, dramatically showing the involvement of these groups in the MEMS field. Over 50 users have used MUMPS to date, for a total of 550 different projects. I figure that 30% of all users are getting their first access to MEMS by going through MUMPS at MCNC.